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W. M. PUGH

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Environmental Classification and Safety*

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Abstract

In order to identify hazardous situations, environments aboard 20 U.S. Navy combat ships were classified according to job type and three environmental dimensions related to perceptions of safety--physical resources, personnel resources, and work procedures. Results indicated that men in Deck and Engineering Divisions sustained injuries at a higher rate than men performing other types of work. Furthermore, regardless of job type, men working in divisions with a combination of low scores on both the personnel resources scale and the work procedures scale tended to have higher injury rates than men in other divisions.

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In a recent study of injuries among U.S. Navy enlisted men aboard ship (Pugh et al., 1976), crew members' perceptions were used to distinguish between safe and unsafe work situations. Situations perceived as unsafe had higher injury rates than situations perceived as safe. Three aspects of the work environment, referred to hereafter as physical resources, personnel resources, and work procedures, were found to be related to perceived safety and subsequent injury.

This earlier study followed a strategy proposed by Gibson (1961) who stated that researchers should focus on the signs of danger and identify "the external sources of potential injury." Pugh and his colleagues (1976) extended this idea and proposed that accidents occurred when a unique combination of circumstances created a situation where damage or injury was likely to result. This approach suggests that the degree of potential hazard in a situation is not merely an accumulation of risk represented by a variety of factors. Instead, various conditions may have no real effects by themselves, but only when these conditions occur in particular combinations are injuries likely to occur.

In the present study, the injury rates for several types of shipboard work environments were examined to determine what types of environments had elevated injury rates and what characteristics discriminated environments with

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high injury rates from those with low injury rates.

Method

Sample

The sample consisted of Navy enlisted men aboard 20 U.S. Navy combat ships, including three destroyers, six guided missile destroyers, three frigates, six destroyer escorts, and two aircraft carriers. Crew sizes ranged from 225 men to 375 men, except for the aircraft carriers which had complements of approximately 4,000 men.

Questionnaires were administered to crew members of each ship near the beginning of a 6- to 8-month overseas deployment. Approximately 70% of the crew of each destroyer-type ship responded to the questionnaire. For the aircraft carriers, aviation personnel were eliminated from the sample, and a stratified sample of the remaining crew members was tested. In this way approximately 10% of each aircraft carrier's crew was tested.

The study was restricted to men who had complete questionnaires, work group location data, demographic data, and illness data and who were in divisions rated by their officers. A total of 2,290 men met these requirements, and the total sample was divided into an analysis sample ($n = 1,147$) and a cross-validation sample ($n = 1,143$). These samples were balanced with regard to ship assignment, work department membership, and pay grade by identifying individuals with each unique ship-department-pay grade combination and arbitrarily assigning half of these individuals to the analysis sample and half to the cross-validation sample.

Test Instruments

The three aspects of the work situation used to discriminate between safe and unsafe environments--physical resources, personnel resources, and work procedures--were scored using data obtained from individual responses to questionnaire items, officer ratings of division resources, and officer ratings of division performance. The questionnaire used was a 400-item instrument designed to assess the physical and social attributes of work environments aboard ship (cf. Jones & James, 1976; La Rocco et al., 1975). Division resources measures were obtained from each division (work group) from the officer in charge of the division. These ratings reflected the quality of equipment and the quality of division personnel. Division performance scores also were obtained from department heads (officers who supervised more than one division) and indicated the performance of the men in the subordinate divisions with regard to quality of performance, completion of planned maintenance schedules, readiness to fulfill commitments, performance under pressure, efficiency of performance, cooperation with other divisions, safety, and quality of division leadership (Jones & James, 1976). Procedures used to combine the measures described above in order to create the physical resources, personnel resources, and work procedures scores are described by Pugh et al. (1976). These procedures yielded scores where: (1) a high physical resources score for an area indicated that work equipment was in good repair, the supply of materials was adequate, and there was sufficient space in which to work; (2) a high personnel resources score reflected conditions where there was an adequate number of men to perform a job and where the men were older, more experienced, and more highly

educated; and (3) a high work procedures score indicated that work was performed according to prescribed procedures by properly trained men who were not under strain induced by heavy work load.

Injury data were obtained from the ships' Medical Departments. A checklist form provided by the researchers was filled out by the hospital corpsman for each dispensary visit. Information regarding illness type, date of visit, and number of days lost from duty were entered on the form.

Procedure

Ratings of physical resources, personnel resources, and work procedures were used to evaluate the work environment of each division. Individuals within divisions were then categorized in accordance with the ratings assigned to their respective divisions. Environmental classification was accomplished by creating a set of dichotomous variables, corresponding to each of the three environmental scales cited above. When the scale value for a division was above the mean, the corresponding dichotomous variable was scored 1; otherwise, it was scored 0. A fourth dichotomy indicated the type of work performed by a division and was created to explore the possibility that the various components of safety merely reflected differential exposure to injury. This final dichotomy was created by scoring Deck and Engineering Divisions 1 and the remaining divisions 0.

In order to determine if these four aspects of the work environment could be used to discriminate groups with high injury rates from those with lower injury rates, the binary variables described above were entered into a regression analysis. In addition, binary variables which represented their two- and

three-way interactions were included. The use of binary variables in regression analysis has been discussed by Cohen (1968).

The criterion score (injury rate) used in these analyses was computed by dividing the number of dispensary visits due to injury for each man by his total days of exposure and multiplying by 1,000.

Results

Classification of Environments

Divisions were classified using only their scores on the three situational components of safety--physical resources, personnel resources, and work procedures. The largest difference in injury rates in the analysis sample was due to the personnel resources dichotomy [$F(1,1145) = 34.72, p < .01$]. Additional variance was accounted for the work procedures dichotomy [$F(1,1144) = 10.94, p < .01$]. A further increment in the amount of criterion variance accounted for was obtained by including a complex combination of interaction terms--physical resources by work procedures, physical resources by personnel resources, and work procedures by personnel resources [$F(3,1141) = 3.06, p < .05$].

When the classification of job type (Deck and Engineering Divisions versus other divisions) was used, it supplanted personnel resources as the single most important discriminator [$F(1,1145) = 52.80, p < .01$]. And, after job type, personnel resources was found to account for the greatest amount of the remaining criterion variance [$F(1,1144) = 5.04, p < .05$]. The only remaining significant increase in criterion prediction was obtained from the work procedures by personnel resources interaction [$F(1,1143) = 5.65, p < .05$].

The trends cited above are illustrated in Figure 1. First, the men were classified according to a job type dichotomy. Men in the Deck and Engineering Divisions sustained injuries at a higher rate than men performing other types of work. Within each job type, men were further classified according to the personnel resources of their divisions. For both job types the trend was the same; divisions with low personnel resources scores tended to have higher injury rates. Finally, the work procedures dichotomy was used to further refine the classification. This further subdivision made a difference only for divisions with low personnel resources suggesting that divisions with a combination of low work procedures and low personnel resources scores tended to have high injury rates while divisions with high scores on the work procedures dichotomy and/or the personnel resources dichotomy tended to have a somewhat lower rate of injuries.

Insert Figure 1 about here.

These results were cross-validated by using the mean criterion scores for each group in the analysis sample as the predicted criterion values for individuals in the corresponding group in the cross-validation sample. This procedure yielded a predictor which significantly correlated with injury rates in the cross-validation sample ($r = .203$, $p < .01$). The similarities in the injury rates for the corresponding groups in the analysis and cross-validation samples may be seen by comparing the means in the final two rows of Figure 1.

Discussion

The environmental classification analyses indicated that exposure to danger

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because of the type of work performed was a significant factor in the occurrence of injury. And, to the degree that job type discriminated between safe versus hazardous divisions in the same way that the physical resources, personnel resources, and work procedures did, it replaced them in the prediction equation. Thus, the predictive utility of the various work environment scores was subsumed once the job type distinction was made. However, addition of the personnel resources and the work procedures variables to job type did improve criterion prediction. Divisions that had both a low personnel resources score (i.e., the men tended to be young, inexperienced, and lacking in education) and a low work procedures score (i.e., the men were not well trained for the jobs they actually performed, did not follow the rules closely, and were placed under strain because of the work load) were likely to have a greater percentage of men injured than other divisions where work of a similar degree of hazard was performed.

The finding that a particular combination of circumstances characterized divisions with elevated injury rates was consistent with the initial definition of an accident. This result suggests that, on the one hand, division officers leading divisions with below average personnel resources might avert accidents by following rules closely and avoiding undue pressures on their personnel. On the other hand, officers in charge of divisions with more mature and experienced men could accomplish the assigned tasks with less rigid conformance to the rules. Moreover, these latter divisions might be expected to function under pressure without the corresponding increase in injuries likely to be experienced

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by the former divisions.

The moderate trends found in this study reflected the fact that the criterion variance (incidence of injury) was severely restricted. However, comparing the present results with those of the earlier study (Pugh et al., 1976) indicates that the classification analysis was an effective technique because the amount of criterion variance accounted for in this study using situational variables alone was equal to the amount of variance predicted in the earlier study using a linear combination of situational variables and individual attributes. Thus, the notion that particular combinations of environmental characteristics have separate and distinct effects on injury rates as opposed to having additive linear effects only was supported.

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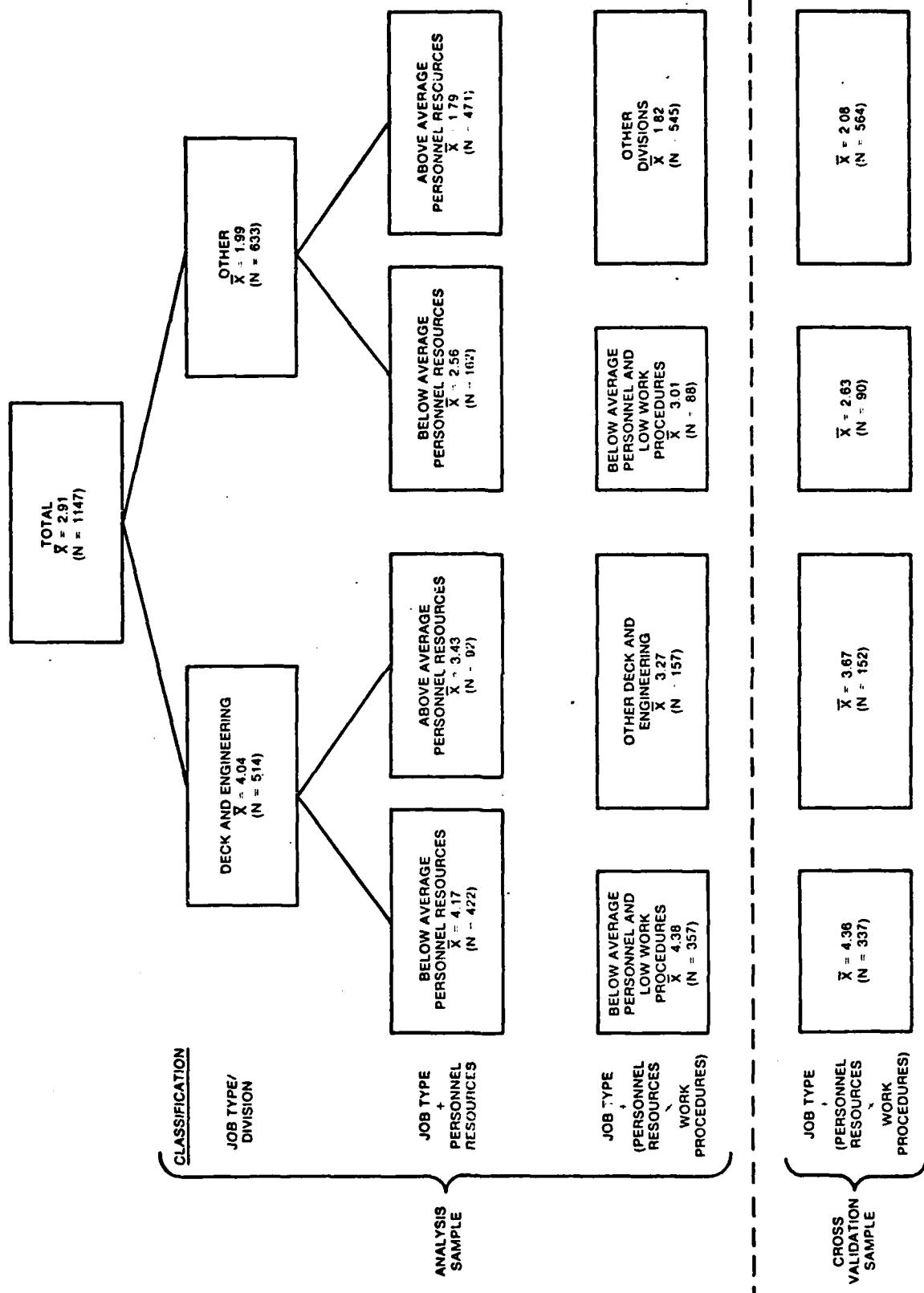


Fig. 1. Mean injury rates by work environment classification.

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